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Phys 132L
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Laboratory 3: Electric Potential and Electric Fields

There are two general methods for predicting the behavior of a probe charge placed in the vicinity of various source charges. One uses the electric field produced by the source charges to determine the force on the charge and subsequently its acceleration. The other considers energy conservation and uses the electric potential produced by the source charges. The two necessary quantities are the electric field and the electric potential produced by the source charges; the electric potential is far easier to measure.

The electric potential, V, produced by a set of source charges establishes an energy landscape. Mapping this landscape, specifically by charting equipotentials, ultimately yields the associated electric field. The direction of the electric field is perpendicular to equipotentials and toward decreasing potentials. The magnitude of the electric field is given by

$$E = \frac{\Delta V}{\Delta s} \tag{1}$$

where ΔV is the electric potential difference between two locations separated by distance Δs (exactly true for infinitesimally small Δs). The aim of this laboratory is to investigate these relationships and to exploit them to determine the electric fields produced by various charge distributions.

1 Electric Potentials and Electric Fields: Parallel Conductors

In this part of the experiment you will investigate the electric potentials and the electric fields produced by two parallel conductors. Each conductor, or *electrode*, consists of a strip of silver paint on black conductive paper.

a) Select a sheet of conductive paper which contains two parallel electrodes. Your instructor will help you follow the instructions (see page 5) for setting this up.

In the following parts you will measure electric potentials relative to that of the negative electrode (connected to the black terminal of the power supply). Throughout this, hold the "COM" voltmeter probe on the negative electrode while varying the position of the "V/DC" probe in the region between the electrodes.

b) Place the "V/DC" probe on the positive electrode and slowly drag it across the gap between the two electrodes. Describe the behavior of the electric potential as you do this. Does it change continuously or jump? Does it increase, decrease or fluctuate up and down as you cross the gap?

drops slowly

c) Copy the electrodes onto the grid sheet attached to this package. On the conductive paper, locate about six points on any single equipotential line in the gap between the two electrodes. Map these onto the corresponding locations on the grid sheet. Draw the equipotential (it could be curved) that passes through these points and label the value of the electric potential on this line. Repeat this for five approximately equally spaced equipotentials. Describe the shape of these lines.

d) To determine the electric field direction, recall that the field points in the direction in which the potential decreases most rapidly. Tape the two probes together so that their heads are not touching and remain fixed a close distance apart. Place the "COM" probe at a location and pivot the other around so that you locate the direction in which V decreases most rapidly. Use this to indicate the field direction on your diagram which contains the equipotentials.

-1

e) Measure the electric potential difference between the negative electrode and a point in the region between the two electrodes. Measure the distance between this point and the negative electrode. Use this to determine the magnitude of the electric field between the electrodes. Repeat this again for another pair of points between the electrodes. Do your results agree? Does the electric field between the electrodes vary appreciably or is it approximately constant?

$V = qs$

$q = \frac{V}{s}$

$\therefore$ q is constant

2 Electric Potential Mapping

The purpose of this exercise is to produce a two-dimensional map (surface plot) of the electric potential produced by the electrodes. The instructor will provide you with a conducting sheet containing two electrodes and will instruct you how to connect them.

a) The conductive paper contains a grid with horizontal and vertical axes marked in centimeters. You will measure the electric potential at most of the intersections of the even axis numbers, working from the middle of the conductive sheet outwards. Set up an Excel spreadsheet in which you will record these numbers. The spreadsheet should consist of a table with labels corresponding to conductive paper grid labels. A *portion* of this is as illustrated.

look for hill

on paper

X

16									
14									
12									
10									
8									
6									
4									
	6	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**

Y

on paper

b) Keep the "COM" probe on the negative electrode and measure the electric potential at an "even number" grid intersection (including the interiors of the electrodes) in the vicinity of the electrodes. Enter this in your Excel table. An **example** is as shown in Table 1.

16									
14									
12									
10									
8				7.1					
6									
4									
	6	8	10	12	14	16	18	20	22

Table 1: **Example** of how to enter data in a table. If you measure 7.1 V at the paper grid intersection point with horizontal number 12 and vertical number 8, you would enter this as in the table as shown.

Continue until your table is filled. The vertical range of your table should span at least 4 to 16 and the horizontal range at least 6 to 22, but more is better. Important notes about this are:

i) Do not enter the units of the measurements - only numbers.

ii) Every cell in your table must contain a number before plotting. Excel treats blank numbers as 0 and this will ruin your plot.

c) Plot the electric potential using the surface plotting facility in Excel. This can be found by following Insert → Charts → Surface. Rightclicking on the chart produces formatting options including 3-D Rotation. Rotate the graph until it's structure is most clearly visible. Show it to the instructor and print this out.

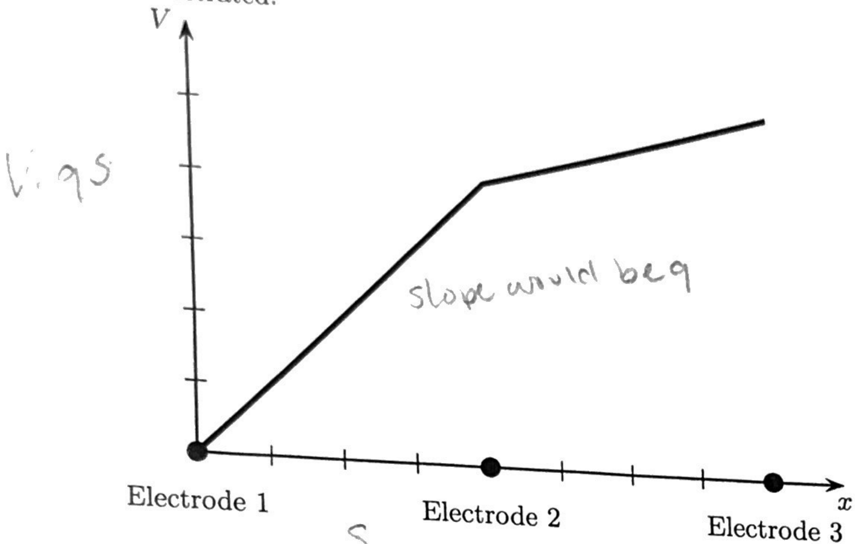
d) Place one probe on the closed electrode (circle or triangle) and the other at various points within the electrode. How does this electric potential difference compare (large, moderate, negligible,...) to that between the electrodes? Does it vary appreciably within the electrode? What does this imply about the electric field within the electrode?

The electric potential difference would be negligible. This implies that the charge is spread equally.

3 Exercises

a) Three parallel electrodes are equally spaced. A graph of electric potential vs distance from the leftmost electrode is as illustrated. The electrode positions are as illustrated.

V: 9s



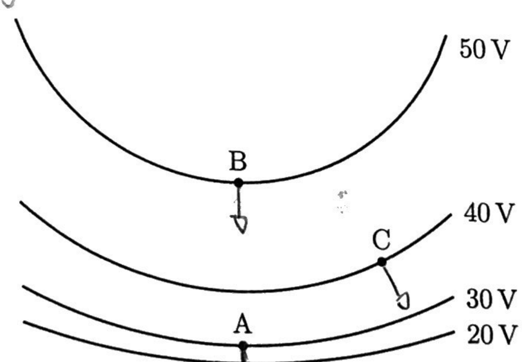
between electrodes 1 and 2 have a larger magnitude of electric field than between 2 and 3.

S

Describe as completely as possible how the magnitude of the electric field between electrodes 1 and 2 is related to that between electrodes 2 and 3.

b) A collection of source charges produces equipotential lines as illustrated. Indicate the directions of the electric fields at points A, B and C. How does the magnitude of the electric field at A compare (larger, smaller, same) to that at B?

The electric field @ A would be larger than @ B



c) Suppose that in the arrangement like that of part 2, the electric potential difference between the electrodes is 10.0 V and that an electron is released from rest at one electrode. Determine the speed with which the electron will be moving just before it hits the other electrode.

Con of E

$U_1 + \cancel{K}^0 = \cancel{U_2}^0 + K_2$

$U_1 = Vq$

$q = 1.6 \times 10^{-19}$

$U_1 = 1.6 \times 10^{-18}$

$K_2 = \frac{1}{2} m v^2 = v = 1.9 \times 10^6$

+

.05 m = s

4 Setting up and Checking the Electrodes

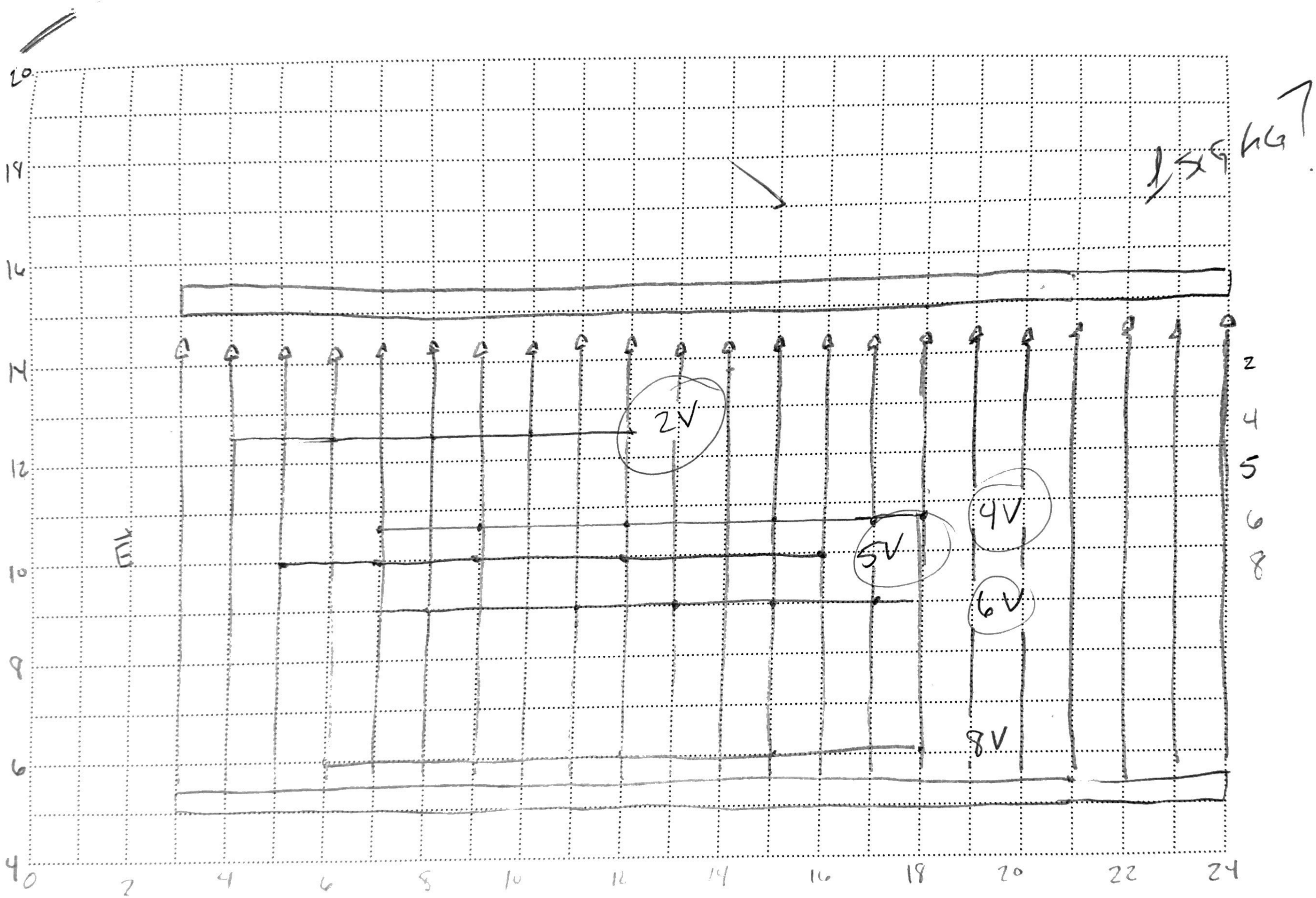
a) The instructor will give you a sheet of conductive paper (black paper with a grid) onto which several silver lines have been drawn. Each of these is an electrode.

b) Connect the positive (red) output of the power supply to one electrode (this is the positive electrode) and the negative (blue) output to the other electrode (this is the negative electrode). Adjust the power supply to provide a voltage of about 10 V.

c) Use the multimeter to measure the potential difference between the two metal thumbtack connectors. The procedure for doing this is as follows. First adjust the multimeter to measure DC Volts (it will then become a "voltmeter.") Then touch the "COM" voltmeter probe to the thumbtack connected to the negative electrode and the "V/DC" probe to the thumbtack connected to the positive electrode. The voltmeter reads the electric potential difference between the two probes.

d) Use the voltmeter to measure the electric potential difference between two widely separated points on the **same electrode.** Repeat this for the other electrode. The difference should be insignificant compared to 10 V.

e) Measure the electric potential difference between two points, **one on each of the electrodes.** Try this at a few different locations. The variation should not depend much (compared to 10 V) on the particular points chosen.


2V
5V
4V
6V
8V

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Part 1

B] It drops slowly from the positive electrode.

C] See map

D] See map

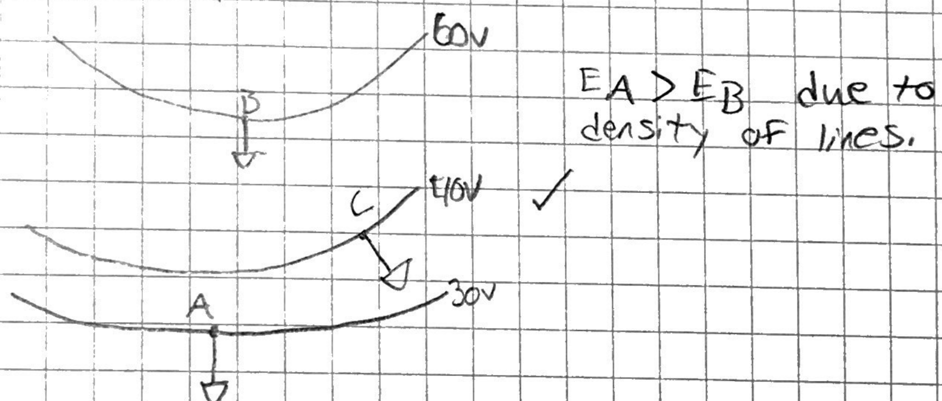
I] $V = QS$ $Q = V/S$ $\therefore$ Q is constant in this field. The field is also uniform so that is another reason

Part 3

A] Between 1 & 2 the slope is greater than between 2 & 3. Since $V = ES$, $E = V/S$, which is what is graphed. Therefore, since between 1 & 2 the slope is greater than 2 & 3, The E-field at points between 1 & 2 is greater than 2 & 3. By how much?

-1/2

B]



$E_A > E_B$ due to density of lines.

C] $E_0 = E_1$

$\cancel{K_0}^{0} + U_0 = K_1 + \cancel{U_1}^{0}$

$U_0 = K_1$

$qV = \frac{1}{2} m v_1^2$

$2qV = m v_1^2$

$v_1^2 = \frac{2qV}{m}$

$v = \sqrt{\frac{2qV}{m}}$

$V = \frac{U}{q}$

$V(q) = U$

$q = 1.60 \times 10^{-19} C$

$m = 9.11 \times 10^{-31} kg$

$v = \sqrt{\frac{2(1.60 \times 10^{-19} C)\, 10 J/C}{9.11 \times 10^{-31} kg}}$

$v = 1.87 \times 10^{6} m/s$

16	9.2	8.7	8.1	6.8	4	5.8	7	7.6	8.1
14	8.3	9	8.7	7.1	5.4	6.5	7.7	8.2	8.6
12	9.1	9.4	9.3	9	8	8.4	8.4	9	9.1
cm 10	10	10	10	10	10	10	10	10	10
8	9.9	9.9	9.9	9.9	9.9	9.9	9.6	9.9	9.9
6	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.5	9.9
4	9.8	9.9	9.9	9.9	9.9	9.8	9.9	9.7	9.9
	6	8	10	12	14	16	18	20	22

Electric Potential Map